DOCUMENT RESUME

ED 482 509 TM 035 004

AUTHOR Azevedo, Roger; Ragan, Susan; Cromley, Jennifer G.; Pritchett, Stacy

TITLE Do Different Goal-Setting Conditions Facilitate Students' Ability to Regulate Their Learning of Complex Science Topics with RiverWeb?

PUB DATE 2002-04-00

NOTE 33p.; Paper presented at the Annual Meeting of the American Educational Research Association (Chicago, IL, April 21-25, 2003).

PUB TYPE Reports - Research (143) -- Speeches/Meeting Papers (150)

EDRS PRICE EDRS Price MF01/PC02 Plus Postage.

DESCRIPTORS Goal Orientation; *High School Students; High Schools; Science Instruction; *Sciences; *Simulated Environment; Water Quality; *Web Based Instruction; World Wide Web

IDENTIFIERS *Self Regulated Learning

ABSTRACT

This study examined the role of different goal setting instructional interventions in facilitating high school students' regulation of their conceptual understanding of ecological systems while using a Web-based water quality simulation environment. Building on the information processing theory of self-regulated learning (SRL) of P. Winne and colleagues, the study examined: (1) students' self-regulation; (2) co-regulation; and (3) the role of the teacher as an external regulator during a knowledge construction activity. Sixteen 11th and 12th graders were randomly assigned to one of two goal-setting instructional conditions (teacher-set goals (TSG)and learner generated sub-goals (LGSG)). Students used RiverWeb (tm), the simulation, collaboratively during a 3-week curriculum on environmental science. The students' emerging understanding was assessed using their pretest and posttest scores, and was also assessed through an analysis of their discourse during several collaborative problem-solving episodes. The LGSG condition facilitated a shift in students' mental models significantly more than did the TSG condition. Students in the LGSG condition were also better at regulating and co-regulating their learning ability during the knowledge construction activity. In general, they planned and monitored their learning more efficiently by creating sub-goals, activating prior knowledge, and engaging in adaptive help-seeking. They also used more effective learning strategies and were more effective in handling task difficulties and demands than was the TSG group. Results provide an initial characterization of the complexity of self- and co-regulated learning in a complex, dynamic technology-enhanced student-centered classroom. (Contains 1 table, 5 figures, and 49 references.) (Author/SLD)

Reproductions supplied by EDRS are the best that can be made
from the original document.

# Do different goal-setting conditions facilitate students' ability to regulate their learning of complex science topics with RiverWeb?

**Roger Azevedo**
University of Maryland, College Park
**Susan Ragan**
Maryland Virtual High School
**Jennifer G. Cromley**
University of Maryland, College Park
**Stacy Pritchett**
Maryland Virtual High School

ED 482 509

PERMISSION TO REPRODUCE AND DISSEMINATE THIS MATERIAL HAS BEEN GRANTED BY
R. Azevedo
TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)



Please address all correspondence to:
Roger Azevedo, Ph.D.
University of Maryland
Department of Human Development
3304 Benjamin Building
College Park, MD 20742
Tel: (301) 405-2799
Fax: (301) 405-2891
E-mail: ra109@umail.umd.edu

U.S. DEPARTMENT OF EDUCATION
Office of Educational Research and Improvement
EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)
☑ This document has been reproduced as received from the person or organization originating it.
☐ Minor changes have been made to improve reproduction quality.
• Points of view or opinions stated in this document do not necessarily represent official OERI position or policy.

**Paper presented at the annual conference of the American Educational Research Association, New Orleans, LA (April 1-5, 2002).**

TM035004



BEST COPY AVAILABLE

**Abstract**

This study examined the role of different goal-setting instructional interventions in facilitating high school students' regulation of their conceptual understanding of ecological systems while using a Web-based water quality simulation environment. Building on Winne and colleagues' information processing theory of SRL, we examined 1) students' self-regulation, 2) co-regulation, and 3) the role of the teacher as an external regulator during a knowledge construction activity. Sixteen 11th and 12th grade high school students were randomly assigned to one of two goal-setting instructional conditions (teacher-set goals [TSG] and learner-generated sub-goals [LGSG]) and used RiverWeb℠ collaboratively, during a three-week curriculum on environmental science. The students' emerging understanding was assessed using their pretest and posttest scores, and was also assessed through an analysis of their discourse during several collaborative problem-solving episodes. The LGSG condition facilitated a shift in students' mental models significantly more than did the TSG condition. Students in the LGSG condition were also much better at regulating and co-regulating their learning during the knowledge construction activity than were TSG students. In general, they planned and monitored their learning more efficiently by creating sub-goals, activating prior knowledge, and engaging in adaptive help-seeking. They also used more effective learning strategies and were more effective in handling task difficulties and demands than was the TSG group. Our results provide a valuable initial characterization of the complexity of self- and co-regulated learning in a complex, dynamic technology-enhanced student-centered classroom. We discuss our findings in terms of expanding existing conceptualizations of SRL, co-regulation, and the role of teachers and peers as external regulating agents. We will discuss how the results will be used to inform the design of new system features to support SRL and co-regulated learning.

**Introduction**

Active learners who efficiently manage their own learning in many different ways are termed self-regulated learners (Boekaerts, Pintrich, & Zeidner, 2000; Paris & Paris, 2001; Winne, 1998, 2001; Winne & Perry, 2000; Schunk & Zimmerman, 1994; Zimmerman, 2002; Zimmerman & Schunk, 2001). Students are self-regulated to the degree that they are cognitively, motivationally, and behaviorally active participants in their learning process (Zimmerman, 1986). These students generate the thoughts, feelings, and actions necessary to attain their learning goals. Self-regulated learning is an active constructive process whereby learners set goals for their learning and then attempt to plan, monitor, regulate, and control their cognition, motivation, behavior, and context (Pintrich, 2000; Zimmerman, 2002). Models of self-regulation describe a recursive cycle of cognitive activities central to learning and knowledge construction activities (e.g., Pintrich, 2000; Schunk, 2001; Winne, 2001; Winne & Hadwin, 1998; Zimmerman, 2000, 2002). In our research, the knowledge construction activity is using a Web-based simulation environment that includes multiple representations of scientific data designed to allow high school students to learn about ecological systems.

In general, models of SRL share certain basic assumptions about learning and regulation, despite the fact that each model proposes different constructs and mechanisms (for recent reviews see Boekaerts, Pintrich, & Zeidner, 2000; Schunk and Zimmerman, 2001). Pintrich (2000) has recently summarized five assumptions shared by all SRL models. One assumption, derived from the cognitive perspective of learning, is that learners are active, constructive participants in the learning process. Learners construct their own meanings, goals, and strategies from the information available from both the internal (i.e., cognitive system) and the external (i.e., context) environment. A second assumption is based on the idea that learners are capable of monitoring, controlling, and regulating aspects of their own cognition, motivation, behavior, and context (e.g., the learning environment). Third, biological, developmental, contextual, and individual constraints can impede or interfere with a learner's ability to monitor or control his or her cognition, motivation, behavior, or context. Fourth, all models assume that there is a goal, criterion, or standard against which the learner makes comparisons in order to assess whether the process should continue or if some type of change (e.g., in strategies) is necessary. In a learning situation, a learner sets goals or standards to strive for in his or her learning, monitors progress toward these goals, and then adapts and regulates cognition, motivation, behavior, and context to reach the goals. Fifth, self-regulatory activities are mediators between personal and contextual characteristics and actual achievement or performance. In other words, it is not just the learner's cultural, demographic, or personality features that influence achievement and learning directly, or only contextual characteristics of the classroom that shape achievement, but it is the learner's self-regulation of his or her cognition, motivation, and behavior that mediates these relationships.

In addition to these critical defining features, models of self-regulated learning typically propose four phases of self-regulated learning (Pintrich, 2000; Zimmerman, 2000). The first phase includes planning and goal setting (Pintrich, 2000; Zimmerman, 2001), activation of perceptions and knowledge of the task (Winne 2001; Winne & Hadwin, 1998), and the self in relationship to the task (Pintrich, 2000; Zimmerman, 2001). The second phase includes various monitoring processes that represent metacognitive awareness of different aspects of the self, task and context (Schunk, 2001). Phase three involves the student's efforts to control and regulate different aspects of the self, task, and context. Lastly, phase four represents various kinds of reactions and reflections on the self and the task and/or context (Winne, 2001; Winne & Hadwin,

1998). In short, self-regulated learners are goal-driven, motivated, independent, and metacognitively active participants in their own learning (Zimmerman, 1990, 2002).

We questioned whether high school students, with little prior knowledge, can successfully regulate their learning of a complex science topic collaboratively with a Web-based simulation environment. This question is a particular concern of our study, which examines whether high school students have the ability to regulate their own learning of a complex scientific topic (i.e., ecological systems) as they work in pairs and use a Web-based simulation environment. The learning takes place over a period of several weeks in a rich learner-centered classroom environment which consists of other classroom materials, peers with varying learning abilities, and several science teachers. This instructional context highlights some of the critical issues that have been recently raised in the SRL literature—role of context in SRL (Alexander, 1995; Hadwin, Winne, Stockley, Nesbit, & Woszczyna, 2001), developmental issues related to the development of SRL (Pintrich & Zusho, 2002), the nature of co-regulation (McCaslin & Hickey, 2001) in complex instructional settings, the role of goals in SRL (Pintrich, 2000; Winne, 2001), and the role of SRL when students use computer-based learning environments (CBLEs) designed to foster understanding of complex science topics (Azevedo, Guthrie, Seibert, & Wang, 2001; Azevedo, Guthrie, & Seibert, under review; Azevedo et al., 2002; Azevedo, Verona, & Cromley, 2001). This instructional context also highlights the need for either converging several SRL models or expanding an existing model (e.g., Winne, 2001) to account for individual knowledge construction, collaborative co-construction, and co-construction in a context that includes peers, teachers, and instructional materials.

Complexity of Issues in SRL and CBLEs: Context, Developmental Aspects, Co-Regulation and Goals.

Understanding the nature of the context in which students learn is a critical part of understanding the nature of SRL. Students' ability to regulate their learning has been affected by contextual variables such as the nature of the task (e.g., an authentic school task vs. a laboratory task), time allotted for the learning activity (a simple task requiring minutes to complete vs. a month-long science curriculum), instructional cues (learner-generated learning goals vs. teacher-set learning goals), instructional materials (e.g., a CBLE vs. books), instructional resources (e.g., peers and teachers), and teaching approaches (e.g., student-centered vs. teacher-centered). It has been argued that different contexts are likely to differentially affect students' ability to regulate their learning (Alexander, 1995). Hadwin and colleagues (2001) have recently shown that students' self-regulated studying behaviors are context-specific. Students reported selectively using different studying tactics based on whether they were reading for learning, completing a brief essay, or studying for an exam. Similarly, student-centered classrooms afford students opportunities to engage in SRL including encouraging students to set their own goals, fostering community building (e.g., emphasizing collaboration), providing flexible guidance during learning (e.g., explicit scaffolded strategy instruction, modeling strategies such as planning and goal-setting), promoting co-construction of knowledge, and allowing for the negotiation of assessment methods (Randi & Corno, 2001). Student-centered methods have been successfully used by proponents of project-based learning to enhance students' understanding of science using CBLEs (e.g., Jackson, Krajcik, & Soloway, 2000; Krajcik, Blumenfeld, Marx, Bass, & Fredericks, 1998; White, Shimoda, & Frederisken, 2000; Vye et al., 1998). However, what has not been investigated is *how* students regulate their learning of science topics in student-centered classrooms using CBLEs. Therefore, it is critical that we understand how the complexity of

contextual variables influences students' ability to regulate their learning by examining the SRL issues related to developmental stages and a limited conceptualization of co-regulation.

There is evidence from the developmental psychology literature that few high school students can effectively regulate their learning, but that those who are self-regulating tend to be the most academically successful (Bronson, 2000; Pintrich & Zusho, 2002; Schunk & Zimmerman, 1997; Zimmerman & Risemberg, 1997). As adolescents grow, become more aware of their own learning and memory processes, and acquire knowledge and strategies, they also become more capable of directing and regulating their learning. To engage in SRL, they must acquire a set of capabilities including planning for learning activities, setting goals for a learning activity, maintaining attention on the material to be learned, identifying and deploying learning strategies, monitoring progress towards goals, evaluating the effectiveness of learning strategies, adjusting goals and learning strategies, and evaluating knowledge gained from the learning activity. Research shows that high school students have difficulties with certain phases and processes related to SRL. For example, high school students often lack the prior knowledge necessary to plan their learning, set learning goals, monitor knowledge construction, and deploy and effectively assess their learning strategies, and also have difficulty assessing their own knowledge accurately (e.g., Pintrich & Zusho, 2002; Pressley, Ross, Levin, & Ghatala, 1984).

The third issue of concern is the distinction between self-regulated learning and co-regulated learning. According to a Vygotskyian perspective on SRL, co-regulation acts as a facilitator of self-regulation (see McCaslin & Hickey, 1996, 2001). Vygostkians assert that SRL has its roots in socially regulated learning—initially, other people (i.e., teachers, parents) help children learn by setting goals for a learning activity, keeping their attention focused on the learning task, suggesting effective learning strategies, monitoring progress towards goals, etc. (Rogoff, 1999). Over time, children assume the responsibility for these processes—they set their own learning goals, stay on tasks, use effective learning strategies, and evaluate their progress and learning. According to this developmental trajectory, co-regulation would bridge other-regulated and self-regulated learning by having teachers and sometimes peers share responsibility for directing the various aspects of learning (McCaslin & Hickey; 1996, 2001). There is a general lack of conceptual clarity regarding the nature of co-regulation during learning between student pairs, student-teacher, and student-teacher-CBLE, even though there is a plethora of studies examining SRL from various theoretical frameworks. Furthermore, there are no empirical studies that we know of that examine the role of co-regulated learning with CBLEs between student pairs, student and teacher, or student and CBLE and the interactions within these pairings.

However, the usefulness of using a Vygotskyan co-regulation framework has yet to be established either conceptually or empirically. The conceptual interplay between self- and co-regulation is of paramount value in our research examining students' understanding of complex science topics in a dynamic, multi-layered technology-enhanced classroom environment. The contextual complexity encountered in our science classrooms is further compounded by the theoretical notions of self- and co-regulated learning and the implicit assumption of many of the CBLEs designed to foster science understanding that using the environment will actually lead to better student understanding (Land, 2000; Hannafin & Land, 1997).

In sum, there are several theoretical and conceptual issues related to SRL that need to be addressed before we can effectively examine how learners regulate their learning during a knowledge construction activity using complex Web-based simulation environments to build sophisticated conceptual understandings of ecological systems. However, due to the complexity

of our instructional context and based on the issues present above, we have begun to empirically investigate one of the initial phases of SRL—goal-setting.

The Role of Goals in Self-Regulated Learning

Goal setting is an integral part of the forethought phase of self-regulation (Schunk, 2001;Winne, 1995, 1996, 2001; Zimmerman, 2000). Allowing students to set learning goals can enhance their commitment to attaining them, which is necessary in order for goals to affect performance. Goals play a major role in models of self-regulated learning (SRL) (see Boekaerts, Pintrich, & Zeidner, 2000; Paris & Paris, 2001; Zimmerman & Schunk, 2001; Zimmerman, 2002). Social cognitive theorists have found that self-set goals promote students' self-efficacy, proximal goals enhance achievement outcomes better than distant goals, and difficult goals enhance student motivation and achievement (see Schunk, 2001 for a review). Similarly, cognitive theorists (e.g., Winne, 2001) include goal setting and planning as critical stages during self-regulated learning. Goals allow a learner to dynamically and recursively engage in several other cognitive and motivational processes as he/she controls task resources (e.g., instructional cues, time allocation, social context), cognitive conditions (e.g., domain knowledge, knowledge of the task, and knowledge of learning strategies), and motivational conditions (e.g., self-efficacy, interest, task value).

Research on students' ability to use goal-setting to regulate their learning of science topics with CBLEs, including simulation and hypermedia environments, is still in its infancy. Azevedo, Guthrie, Seibert, and Wang (2001) recently examined the role of different goal-setting instructional interventions in facilitating students' shift to more sophisticated mental models of the circulatory system as indicated by both performance and process data. Azevedo et al. (2001) adopted Winne and colleagues' IPT model of self-regulated learning (Winne, 2001; Winne & Hadwin, 1998) and empirically tested the model by examining how students regulated their own learning when using a hypermedia environment to learn about the circulatory system. Twenty-four undergraduate students were randomly assigned to one of three goal-setting instructional conditions (learner-generated sub-goals, top-down, and bottom-up) and were trained to use a hypermedia environment to learn about the circulatory system. Pretest, posttest, transfer test, and verbal protocol data were collected using a pretest-posttest comparison group design with a think-aloud methodology. Findings revealed that the learner-generated sub-goals condition facilitated the shift in learners' mental models significantly more than did the other comparison conditions. Learners in the learner-generated condition were also much better at regulating their learning during the knowledge construction activity. In general, they planned and monitored their learning more efficiently by creating sub-goals, activating prior knowledge, and engaging in self-questioning. They also used more effective learning strategies, were more effective in handling task difficulties and demands than comparison groups, and expressed interest in the topic. Their results provide a valuable initial characterization of SRL across several goal-setting instructional conditions during an individual knowledge construction activity.

In a second study, we (Azevedo, Seibert, Guthrie, Cromley, Wang, & Tron, 2002) continued our investigations on how different goal-setting instructional interventions facilitate students' understanding of complex science topics with hypermedia. We continue to expand on Winne and colleagues' model of SRL (1998; 2001) by including the bottom-up and learner-generated conditions and testing other goal-setting conditions. We added a strategy instruction condition where the students received a 30-minute training session in how to regulate their learning, and we also added a co-regulation condition where the student had access to a nurse

practitioner who assisted in regulating the students' learning. Forty undergraduate students were randomly assigned to one of four goal-setting instructional conditions (co-regulation, strategy instruction, learner-generated sub-goals, and bottom-up) and were trained to use the same hypermedia environment to learn about the circulatory system. Findings revealed that the co-regulation and strategy instruction conditions facilitated the shift in learners' mental models significantly more than did the other comparison conditions. Learners in the co-regulation condition benefited by having the tutor co-regulate their learning by planning their goals, monitoring their emerging understanding and providing scaffolding, using effective strategies, and providing motivational scaffolding. Learners in the strategy instruction condition also made significant knowledge gains but regulated their learning differently, since they did not have the tutor to co-regulate their learning. Learners in the learner-generated sub-goals and bottom-up conditions were less effective at regulating their learning and exhibited great variability in their ability to self-regulate their learning during the knowledge construction activity. Our results are beginning to provide valuable empirical evidence about the effects of different goal-setting conditions on students' ability to self-regulate and co-regulate their learning with CBLEs.

In the present study, we considered the effects of goal-setting conditions on high school students' ability to regulate their learning of a complex science topic when using RiverWeb, a Web-based simulation hypermedia environment. Similar to Azevedo et al. (2001), we used a model-driven approach by expanding Winne and colleagues' IPT model to examine the role of goal-setting in a dynamic, multi-layered technology-enhanced classroom environment.

A Model of SRL in a Multi-Layered Dynamic Technology –Enhanced Classroom Environment

Because SRL is relevant to so many aspects of learning, diverse theoretical perspectives have been proposed as useful for examining SRL. These include theories based on information processing (Winne, 2001; Winne & Hadwin, 1998), Piaget's constructivist theory (Paris, Byrnes, & Paris, 2001), Vygotsky's sociocultural theory (McCaslin, 1989; McCaslin & Hickey, 2001), and social learning theories (Pintrich, 2001; Schunk, 2001; Zimmerman, 2002) (for a recent review of the various theoretical perspectives see Zimmerman & Schunk, 2001).

We have reached a critical period in SRL research where either theoretical convergence or expansion is needed due to the overlap in constructs and because each theory uses a "lens" of different magnification to study SRL (Zimmerman, 2001; Zimmerman & Schunk, 2001). Building on Winne and colleagues' SRL model (Winne & Butler, 1995; Winne & Hadwin, 1998; Winne, 1998; 2001), we used their theory to study high school students' self- and co-regulated learning of ecological systems using RiverWeb, a Web-based simulation environment, in a learner-centered classroom.

We expanded their model and analyzed students' SRL at three levels—1) individual construction of knowledge; 2) co-construction between a pair of students; and, 3) teacher monitoring of the co-construction process between a pair of students. Level 1 represents the construction of knowledge at the individual student level. Level 2 includes two individual IPT models, one for each student, representing co-regulation as both students co-construct knowledge with RiverWeb. Level 3 is an extension of Level 2, in that the teacher co-regulates the student pair's Level 2 co-construction of knowledge by monitoring the activity. Due to the complexity of SRL, our research strategy is aimed at examining the effects of manipulating one of the initial phases of SRL—goal-setting.

Winne and colleagues' information processing model of self-regulation accounts for students' cyclical and recursive cycles of control and monitoring during the four phases of self-

regulated learning—perceiving tasks, setting goals and plans, adopting tactics, and enacting tactics. SRL updates self-knowledge and perceptions of the task's changing states, thereby creating information that self-regulated learners can (if they so choose) use to select, adapt, or generate tactics and strategies.

According to Winne and Hadwin (1998, 2001), self-regulating learners go through four cyclical and iterative phases. During the first phase the learner processes information about the conditions that characterize the task; that is, the learner constructs a perception that defines what the task is (Butler & Winne, 1995; Winne, 1997). Two main sources of information contribute to definitions of a task: the first is *task conditions* (information about the task that the learner interprets based on the task environment, such as a list of general teacher-set learning goals). The second source of information is *cognitive conditions,* information that the learner retrieves from LTM and the learner's estimation of prior knowledge, memory of anxiety about similar tasks, and attributions related to ability. Once information about these task and cognitive conditions is active in working memory, the student integrates it to construct an idiosyncratic definition of the task.

In phase two, the learner frames a goal and assembles a plan to approach it. According to Winne and colleagues (1998; 2001), goals have profiles of standards and each standard in a goal's profile is a value against which products can be monitored throughout the task. By cycling through phase two, goals can be updated as work on the task itself proceeds (in phase three). According to the model, once goals are active, learners then proceed to learn by using the COPES (conditions, operations, products, evaluations, and standards) script for the task.

In phase three, the learner applies the tactics and strategies identified in phase two. Search tactics copy information into WM from LTM that relate to the student's definition of the task. Each product created by carrying out a tactic or strategy has facets (similar to goals) that can be modeled in the same shape as the goal profile from phase 2. Monitoring compares the shape of the goal profiles and generates internal feedback. Phase four is optional; according to the model, the learner may decide to make major adaptations to the schemas that structure how self-regulated learning is carried out.

This model also postulates that metacognitive monitoring, metacognitive control, and feedback are key features of self-regulated learning which take place in all four phases (Butler & Winne, 1995; Winne 1996, 1997, 2001; Winne & Hadwin, 1998). Without cognitive evaluations about the differences between a) the current profile of work on a task and b) goals that specify standards for a satisfactory product, there is no guidance about how to regulate learning. Monitoring produces information—as a list of both matches and mismatches between the standards for a task, and mismatches between the standards for a task and a representation in WM of the product(s) of (a phase of) a task. Within the limits of cognitive resources and given particular external task conditions, the updates from each phase afford potential for the learner to exercise metacognitive control that adapts engagement in mid-task (Winne, 2001).

Overall, there is a limited amount of psychological research that addresses a) whether students regulate their use and generation of sub-goals across domains and b) the complexity of SRL between individual and collaborative pairs and the teacher in students' learning of complex science topics (e.g., ecological system), especially with students using dynamic, non-linear, random-access instructional Web-based simulation environments. Therefore, a critical aspect of this study is to determine the extend to which we can use Winne and colleagues' model to account for levels 2 and 3 of our model in our complex instructional context. For example, do students engage in effective help seeking during co-regulated learning by asking either peers or

teachers for assistance during the knowledge co-construction activity? Do students set sub-goals and monitor progress toward them? There is a need for more clarity with respect to the role of goals and goal-setting during knowledge construction activity from CBLEs which contain multiple representations (e.g., text, diagrams, graphs, scattterplots). There is also a need for more detail with respect to how other sub-components of self-regulated learning (e.g., planning, monitoring, strategy use, handling of task difficulty and demands, and interest) are related to teacher-set and self-set goals and sub-goals during learning of complex science topic with a simulation environment.

Based on Winne and colleagues' (1998, 2001) model of SRL, we hypothesized that the questions we posed to students would serve as a series of teacher-set sub-goals that would scaffold and therefore facilitate students' understanding (from pretest to posttest). The questions would allow them to cognitively monitor their search of the environment and the answers to each question (i.e., products of information processing) and compare these to their standard (i.e., overall learning goal). This would allow them to generate feedback regarding any discrepancy between current understanding and the overall learning, and permit them to exercise cognitive control to reduce any discrepancies in learning.

The *learner-generated sub-goals* (LGSG) condition students were given the four general learning goals and were allowed to set their own learning sub-goals while using the RiverWeb WQS simulation to learn about ecological systems. Based on Winne and colleagues' (1998, 2001) model of SRL, we hypothesized that the students would engage and regulate their learning by generating their own learning sub-goals which might lead them to be more cognitively engaged during learning, allow them to engage in metacognitive monitoring of their current understanding, and therefore produce internally generated feedback, allowing them to again monitor their learning and adjust it accordingly. These students would also engage in co-regulation of their learning and engage in adaptive help-seeking behavior from the teachers and peers.

In the *teacher-set goals condition* (TSG), each student pair followed a detailed script (in the form of questions) design to enhance their understanding of the complex issues related to water quality and land use. This condition was designed to examine whether providing students with detailed scripted teacher-set goals would enhance their understanding of issues related to ecological systems. These students would be limited in their ability to co-regulate their learning and not engage in adaptive help-seeking behavior from the teachers and peers.

## Research Questions

In this study, we investigated how different goal-setting instructional interventions facilitate high school students' shift from less- to more sophisticated mental models of a complex system (i.e., issues related to land use, water quality, and ecological system) in a complex instructional context. Two specific research questions are addressed in this paper. First, how do different goal-setting instructional conditions influence students' ability to shift to a more sophisticated understanding of ecological systems? Second, how do goal-setting conditions influence students' ability to regulate their learning from Web-based simulation environments? We also discuss how the results of our study will be used to inform the design of new system features to support SRL and co-regulated learning.

## Method

### Participants

Sixteen 11th and 12th grade high school students (11 girls and 5 boys) from an environmental science class volunteered to participate in this study. Ages ranged from 16 to 18 years. The students come from diverse socioeconomic and racial backgrounds, and represent a wide spectrum of academic abilities. Thirty one percent ($n$ = 5) were African American, 31% ($n$ = 5) were Caucasian, 19% ($n$ = 3) were Hispanic, and 19% ($n$ = 3) were Asian. They had low prior knowledge, having only taken a biology course in which the unit on ecology covered population dynamics in various ecosystems, photosynthesis, biotic diversity, abiotic factors, and interdependence of organisms. Data were collected during February and March 2001, two months prior to the end of the school year.

### Research Design

We used a pretest-posttest comparison group design (16 students randomly assigned to one of two instructional conditions—teacher-set goals (TSG) and learner-generated sub-goals (LGSG). We also collected video and audio data on one-half of the students while they worked in groups of two using the RiverWeb Water Quality Simulator (WQS) to learn about ecological systems.

### Instructional Context

In a typical high school environmental science course, a unit is devoted to water quality and the impact of land use on the pollutants that find their way into streams, rivers, and eventually, the ocean. Many high schools have identified their own wetlands on or near the campus so that students may take samples of water on which to perform measurements of pH, dissolved oxygen, and other water quality indicators. These activities give the students hands-on experience about the nature of the water in their own watershed. The next step for many high school students would be to investigate how water quality changes across different locales, but that would require field trips that are both expensive and time intensive. Yet in order for students to understand the differential impact of agricultural, commercial, urban, suburban, manufacturing, and forested land uses on water quality, students need to have some kind of experience with each. The RiverWeb Water Quality Simulator (WQS) is designed to provide students with a simulated field trip through a prototypical watershed.

In the environmental science course used for this study, the classroom teachers and students spent three weeks studying watersheds in preparing for their investigations with RiverWeb. In week one, they begin with a review of graph interpretation skills, which they then applied to a demonstration of evaporation and condensation in a closed system (the water cycle experiment). The students also received a demonstration of the STELLA™ modeling and simulation environment and went to the computer lab to construct a computer model of the water cycle experiment. They started to construct their STELLA™ models in the next class period. In week two, they spent three class periods constructing and refining their STELLA™ models. In week three, the science teacher engaged students in a classroom discussion of the issues related to land use and water quality.

The RiverWeb SM Water Quality Simulation Environment

The RiverWeb Water Quality Simulator (WQS) is a Web-based environment (http://mvhs1.mbhs.edu/riverweb/index1.html) developed at Maryland Virtual High School and linked to the RiverWeb SM Program originating from the National Center for Supercomputing Applications (NCSA). Targeted at the grades 8-12 science and math curriculum, the WQS depicts the effects of various land uses on water quality in an archetypal watershed. Students access WQS monitoring stations to explore how different land uses, including pristine forest, agriculture, lumbering forest, residential area, commercial/industrial area, wetlands, and urban area, affect water quality. Each water monitoring station allows students to test for physical and chemical characteristics of the tributary, such as total flow and nitrogen concentration. By limiting each sub-watershed to one land use, the effect of that land use on can be seen on the quality of the water that students "test" within its boundaries. The cumulative effect of the combined land use determines the water quality shown by the indicator values found at a common river outflow (see area 7 on Figure 1).

After the user logs in, a map of the archetypal watershed appears (see Figure 1). Water quality monitoring stations located throughout the watershed are also depicted on the map. The user may click on the map to investigate any sub-watershed using the RiverWeb graph window. By default, the graph window displays the variation of nitrogen over time in Station 0 in the top window, and precipitation over time in Station 0 in the bottom window (see Figure 2). Other indicators may be selected; for example, the student might compare nitrogen concentration between two stations (e.g., residential area vs. wetlands) and/or compare different indicators at the same station (e.g., phosphorous vs. dissolved oxygen in the urban area). In addition, reducing the range of days for each graph provides the ability to zoom in on a particular time period and allows the student to investigate daily and seasonal variations.

---

Insert Figure 1 about here

---

---

Insert Figure 2 about here

---

A tour, which may be selected at login, uses frames to combine the WQS with instructions leading the user through most of the simulator capabilities. Clicking on a hyperlink in the graphical display invokes the Web-based notebook. Linked to a flexible database on the server, a digital notebook keyed to currently selected indicators provides a space for students to record their observations, pose hypotheses, and answer questions designed to promote conceptual understanding as they explore connections between watershed variables. Teachers can use the notebook to structure their students' explorations by customizing the questions to fit the needs of their students and curriculum and to assess student learning.

Students examine the time series reports and scatterplots available through the graph page and then record their observations in the digital notebook. Using the time series graphs, students are able to see the impact of seasonal changes on certain indicators. Using the scatterplots, students are able to discover correlations between variables, such as the relationship between water temperature and dissolved oxygen. The goal is to foster student understanding of the complex relationships among the many land uses, indicators, and water quality in the watershed.

To gain this understanding, students are given instruction in graph interpretation, they then answer open-ended questions which demand explanations of concepts and relationships, and then construct concept maps. Once students have developed an explanation for how land use influences water quality, they discuss the recommendations that should be made to local policymakers to solve problems, applying their understanding to evaluate relative benefits and costs of different strategies aimed at mitigating non-point pollution within the watershed.

Data Sources and Measures

Several data sources were used to obtain an in-depth understanding of students' emerging understanding of science phenomena and to examine the effects of goal-setting conditions on students' ability to regulate their learning with RiverWeb. A total of 15 hours of video and audio data were collected, and subsequently transcribed for fine-grained analysis. The students' emerging understanding and ability to regulate their learning was assessed through an analysis of student interactions during science inquiry activities. Video and audio data were collected on one-half of the student pairs (i.e., 2 TSG groups and 2 LGSG groups) during all on-line science inquiry sessions with RiverWeb. This allowed for in-depth analysis of students' individual, co-construction, and teacher and peer scaffolding of knowledge while they engaged in science inquiry activities with the WQS. In addition to the video and audio data of student pairs, we also collected notebook entries, prediction statements, pretests, posttests, and concept maps.

The paper-and-pencil materials consisted of a pretest and a posttest. Three science teachers in consultation with a faculty researcher and graduate student constructed all of the paper-and-pencil materials. The pretest and posttest included seven complex questions which required students to: (1) explain underlying ecological phenomena, (2) describe scientific procedures for finding the source of toxins, (3) describe and hypothesize daily and seasonal variations depicted on several line diagrams, and (4) construct a concept map illustrating the relationships between water quality indicators and land use.

The questions were designed to give the student an opportunity to demonstrate their understanding of the various issues related to water quality. Question 1 was designed to determine if the students understood whether pollutants found at the mouth of a river come from runoff from land uses areas upstream. Question 2 was designed to assess whether students understood that a methodical process of testing water at various sites upstream must be used to discover the actual source of pollutants found at the mouth of the river. Question 3 was designed to assess whether students understood that a parking lot results in more runoff and, subsequently, more sediments and toxins in the water and also increases the temperature of the runoff, resulting in lower levels of dissolved oxygen. Question 4 was designed to assess whether students understood that seasonal variation rises and falls with the seasons as well as showing some daily variation. Water quality indicators, which are affected by air temperature and human seasonal activity, will demonstrate seasonal variation in the graphs. Question 5 was designed to assess two concepts: whether students understood that the scale on the y axis of a graph must be included in the interpretation of the graph, and that land usage affects nitrogen concentration. Question 6 was designed to assess whether students understood that the scale on the y axis of a graph must also be included in the interpretation of the graph and that both precipitation and land use affect runoff. In question 7 students had to draw a concept map to show that they understood how various factors affect water quality. Questions 1, 2, and 3 were constructed response type questions. Questions 4 and 5 included a combination of time series graph interpretation and constructed responses. Question 6 was a scatter plot graph interpretation questions. Question 7 asked the students to draw and label a concept map. The posttest was identical to the pretest.

Procedure

The students were randomly assigned to one of two groups: teacher-set goals ($n$ = 8) and learner-generated sub-goals (LGSG) ($n$ = 8) following the 3 weeks of preparation for investigations with RiverWeb. After assigning students to conditions, we formed 4 teacher-set goals groups and 4 LGSG groups. The environmental science unit with RiverWeb took place over eleven 90-minute blocks over a period of two months. During this period the students engaged in several activities including graph interpretation tasks, constructing water cycle models with Stella™, conducting laboratory experiments, and using RiverWeb to explore the relationship between water quality indicators and land use. Performance data were collected for all students. Videotapes and audiotapes were collected from two of the teacher-set goals (TSG) and two learner-generated sub-goals (LGSG) groups on three separate occasions over a 1-month period. In total, we collected 15 hours of audio and video data over three days (four student pairs during two 90-minute classroom period and two groups during the final presentations). One researcher acted as a complete participant during the data collection period. She is an experienced environmental science teacher who introduced the science activities to all of the students and provided scaffolding during activities. The regular classroom teacher and a visiting teacher also provided scaffolding during all science activities. The other two researchers acted as complete observers rather than participants in the classrooms, remaining on the sidelines to take notes and manage taping equipment, interacting minimally with the students and teachers during class periods. Taping was done for whole class periods during which the teachers moved in and out of interaction with individual groups as they tackled the science inquiry questions. Therefore, data was gathered as the groups of target students worked both with and without teacher assistance.

Following the classroom discussions, students were given a six page pre-lab worksheet in preparation for the RiverWeb activity. The students were asked to write a) several paragraphs describing several best management practices (e.g., stream buffer, strip cropping), b) interpret and label several graphs and scatter plots illustrating seasonal changes in air temperature and concentrations of chemical indicators, c) sketch and label the axes of a graph to illustrate how water temperature in a river might vary over the course of a year, d) generate hypotheses regarding the shape of graphs and scatter plots, e) find corresponding data on two graphs, and f) add connectors (i.e., relationships between concepts) on a teacher-constructed concept map illustrating the pathways that energy and nutrients travel along in an estuarine environment.

In week one, students completed their pre-lab activity. In the second class of week one, the teachers administered the pretest to all sixteen students during their science class. In the last class meeting of the week, the teachers led a classroom discussion of water quality indicators, and subsequently the students constructed an initial concept map of the issues related to land use and water quality. In week two, students in both groups (i.e., TSG and LGSG) were handed their RiverWeb scripts and worked with their partners to complete their RiverWeb WQS activities in the computer lab. The teachers provided instructions for the learning task. The instructions were slightly different for each of the experimental conditions. The following instructions were read and presented to the students in writing.

For the learner-generated sub-goals (LGSG) condition the script consisted of a 2-page handout with directions for how to create a concept map and with the following instructions: "*You are going to explore the relationships among the indicators in your concept map by using RiverWeb. As you work, keep in mind these four questions: (1) How does land use impact the water quality at a station? (2) How does the land use at a station affect the water quality at the*

*mouth of the river? (3) Investigate interactions between indicators – which indicators impact other indicators? Why does the interaction exist? (4) How does the water quality at a station change after the best management practice is implemented?"* The instructions for the teacher-set goals (TSG) condition were identical and also included as part of their handout a list of all possible combinations of indicators, which each pair should investigate in RiverWeb. The list and sequence of indicators was designed by the teachers to increase TSG students' understanding of the complex issues related to land use and water quality.

Students spent three class periods using the WQS to explore the complex issues related to land use and water quality. The WQS was used as an environment for the students to deepen their understanding of the complex relationships in the watershed. In week three, students met in their TSG and LGSG groups (i.e., two groups of 8) and the teachers had each group discuss their findings and together build a final concept map representing the understanding the entire group (i.e., 8 members of each group). In the second class period of week three the teachers administered the posttest to all students during their science class.

Data Analysis

In this section we describe the scoring of the students' answers to the pretests and posttests, the coding of the students' mental models based on the concept maps they constructed on their pretests and posttests, the coding of the number of relationships and connectors in the each groups final concept map, and inter-rater reliability measures.

Scoring of Students' Answers to Pretest and Posttest Questions. Two teachers constructed a rubric for scoring the students' responses to the pretest and posttest questions by initially scoring a subset (30%) of all the pretests and posttests. The rubric was refined and the two teachers scored all 32 tests individually using the revised rubric. Questions 1, 2, and 3 were each given a single score; questions 4 and 6 each had four parts and so the two questions were given four scores each; and, question 5 had two parts and so it was given two scores. This yielded 13 separate scores for each student's pretest and posttest, which were combined to calculate the each student's overall (questions 1-6 on the pretest and posttest) score out of 60, which was then converted into a percentage.

Coding the Students' Mental Models Based on the Concept Maps from Pretest and Posttest. Our analyses focused on the participants' shifts in mental models based on the goal-setting instructional interventions. A mental model is an internal mental representation of some domain or situation that supports understanding, problem solving, reasoning, and prediction in knowledge-rich domains (Gentner & Stevens, 1983; Markman & Gentner, 2001). The mental models approach has been used extensively to explain reasoning about a number of domains including physical systems and mechanisms (Hegarty & Just, 1993; Narayanan & Hegarty, 1998), electrical circuits (White, Shimoda, & Frederiksen, 2000), circulatory system (Azevedo et al., 2001, 2002, under review; Chi, 2000; Chi et al., 1994, 2001), development of astronomical knowledge (Vosniadou & Brewer, 1992), and the nature of matter (Hogan, 1999).

In order to have a coherent understanding of the effects of different land uses on water quality, an intricate system of relations must be understood not only locally, but also system-wide as well. The relations include within-a-component (e.g., fluctuations in individual indicators), between-component (e.g., fluctuations between water quality indicators) , and hierarchical relations (e.g., effects of different land uses on water quality indicators), as well as

complex relationships between water temperature, nitrogen, and toxins on dissolved oxygen as well as relationships between nitrogen, toxins, phosphorous, heavy metals on pH. We developed an initial approach based on the extensive research on the use of mental models to analyze students' conceptual understanding of complex science topics (e.g., Chi et al., 1994, 2001) and subsequently extended it, with the assistance of our science teachers, to include the knowledge that was presented in the RiverWeb WQS and the students' understanding based on their performance on the pretests and posttests.

One goal of our research was to capture the initial and final mental model that each participant had of the ecological system. This analysis depicted the status of each student's mental model prior to and after learning, as an indication of representational change that occurred with deep understanding. In our case, the status of the mental model refers to the correctness and completeness in regard to the identification of indicators; the relationships between the indicators and land use; and the relationship among the indicators, land use and best management practices.

We followed established methods used by researchers (e.g., Chi et al., 1994) to analyze the students' mental models. In brief, a student's initial mental model of how the *ecological system* works was derived from their (initial) concept map from question #7 on the pretest. Similarly, a student's final mental model of how the ecological system works was derived from their (final) concept map from question #7 on the posttest. As a result, we created seven general types of mental models, which represent the progression from no model to the most accurate: (1) no understanding, (2) basic global concepts, (3) basic model with multiple levels of causality, (4) intermediate model with multiple levels of causality, (5) advanced model with multiple levels of causality, (6) advanced model with multiple levels of causality with runoff, and (7) advanced model with multiple levels of causality with best management practices. A complete description of the necessary features for each mental model is provided in the Table 1.

---

Insert Table 1 about here

---

Coding and Inter-Rater Reliability Measures. Each teacher scored each student's questions (and sub-parts) on their pretest and posttest (i.e., 6 questions with a total of 13 scores x 16 students x 2 tests = 416 individual scores). Each teacher was instructed to independently code all 416 answers on the pretests and posttests. The inter-rater reliability was established for the scoring of the learners' pretest and posttest answers by comparing the individual coding of the two high school teachers, who derived the scoring rubric for each of the sub-parts to each of the six questions presented on both pretest and posttest. There was agreement on 362 out of 416 scores yielding a reliability coefficient of .87. For mental models, inter-rater reliability was established by recruiting and training a high school teacher to use the description of the mental models (see Table 1). She was instructed to independently code all 32 selected protocols (pretest and posttest concept maps of the ecology system from each student) using the 7 mental models of the ecology system previously described and presented in Table 1. Her coding was compared to another science teacher and there was agreement on 28 out of a total of 32 student concept maps yielding a reliability coefficient of .88. Inconsistencies were resolved through discussion between the teachers and the experimenters.

## Results

The data analyzed in this study consisted of outcome measures from pretests, posttests, and concept maps from each of the 16 students, and the verbal protocols collected during learning with the RiverWeb WQS from one-half of the students in each instructional group. We used the outcome measures to analyze changes in students' conceptual understanding based on the pretest and posttest scores and scores on their concepts maps. We also analyzed the shift in the sophistication of students' mental models based on our seven mental models of ecology. We also analyzed the correct placement of arrows and labeling of relationships made by students on their final group concept maps. Students' verbalizations were analyzed to examine the effects of the two goal-setting instructional conditions on the nature of self-regulated learning using to our extension of Winne and colleagues' model of self- and co-regulation in a multi-layered dynamic technology-enhanced classroom environment. We also provide a qualitative description of how a "typical" student in each of the two goal-setting conditions would regulate their learning of the ecology systems with the WQS, based on the verbal protocols. Analyses are reported that address the guiding questions.

*Question 1: How do different goal-setting instructional conditions influence students' ability to shift to a more sophisticated understanding of ecological systems?* The results for this question are based on students' understanding as shown on the pretest and posttest scores and the shift in their mental models from pretest to posttest. We also had the science teachers analyze the groups' final concept maps.

Individual Knowledge Construction

The analyses of the pretests and posttests used a 2 (teacher-set goals-TSG, learner-generated set goals, LGSG) by 2 (pretest, posttest) design. The first factor, Instructional Condition, was between-groups, and the second factor, Time, was a within-subjects measure. The number of participants in each cell is 8 for all analyses.

Students' performance on the pretests and posttest (questions 1 through 6) was analyzed to determine whether the different goal-setting conditions, embedded in two instructional interventions, facilitated students' understanding of the complex relationships in a watershed. A 2 X 2 repeated measures ANOVA on the pretest and posttest data found a significant main effect of time, $F(1, 14) = 70.76$, $MSE = 8450$, $p < .05$, and a significant interaction between condition and time, $F(1, 14) = 7.56$, $MSE = 903$, $p < .05$. Simple main effect comparisons found no significant differences between the conditions at pretest ($t[14] = 1.34$, $p > .05$) and posttest ($t[14] = 0.42$, $p > .05$). LGSG students outperformed the TSG students on the posttest ($M = 69.5$, $SD = 15.1$ and $M = 60.3$, $SD = 11.9$, respectively), even though the pretest scores for both groups indicated that students in the TSG condition had a slight advantage over the LGSG group on the mean on the pretest ($M = 38.4$, $SD = 12.3$ and $M = 26.4$ $SD = 22.1$, respectively) (see Figure 3).

---

Insert Figure 3 about here

---

Students' final concept maps (question 7 on the pretests and posttests) were analyzed to determine whether the different goal-setting conditions influenced students' shift to a more sophisticated mental model of this topic represented in RiverWeb. A 2 X 2 repeated measures ANOVA on the students' scores for question 7 on the pretest and posttest data showed a

significant main effect of time, $F$ (1, 14) = 44.29, $MSE$ = 2235, $p < .05$, and a significant interaction between condition and time, $F$ (1, 14) = 4.69, $MSE$ = 802, $p < .05$. Simple main effect comparisons found no significant difference between the two conditions at pretest ($t$ [14] = 0.38, $p > .05$), but there was a significant difference at posttest ($t$ [14] = 2.33, $p < .05$). Pretest scores indicated that there was no clear advantage between the TSG and LGSG groups in students' understanding of the issues related land use and water quality ($M$ = 9.13, $SD$ = 10.1 and $M$ = 7.25, $SD$ = 9.57, respectively). However, on the posttest students in the LGSG condition significantly outperformed the TSG group ($M$ = 48.74, $SD$ = 19.9 and $M$ = 30.3. $SD$ = 10.2, respectively) (see Figure 4).

---

Insert Figure 4 about here

---

Groups' Final Concept Maps

We also analyzed each group's understanding of the issues related to land use and water quality based on the final concept map constructed by all students in each group. The three teachers indicated that the concept maps show that the two groups demonstrated a general understanding of the relationships in the water quality unit, but that there were some gaps in the students' understanding of the details (see Figure 5). Since the concept maps represent a group effort, they may reflect the understanding of the dominant member of the group. We observed on the videos that the person with the deepest understanding of the water quality indicators was the one who contributed the most to the design of the concept map for each group. Therefore, the group-created concept maps do not reflect the knowledge of individual group members.

---

Insert Figure 5 about here

---

We can conclude from the first set of findings that the LGSG condition facilitated students' conceptual understanding significantly more than did the TSG. This result indicates that the increase in understanding was greater for the LGSG condition. We now report the processing of learners' self- , co-regulated and external regulated learning based on our model to explain the quantitative differences reported previously.

*Question 2: How Do Goal-Setting Conditions Influence Students' Ability to Regulate Their Learning from Web-Based Simulation Environments?* In this section we present our analysis of the audio and video data in terms of our three models: individual learning, co-construction, and teacher-scaffolded learning. For individual learning and co-construction, we present examples from both the LGSG and TSG groups. However, in teacher-scaffolded learning, teachers provided almost identical scaffolding for the two groups, so we present these examples together.

Overall, RiverWeb fostered student engagement in sustained inquiry-based activities and scientific reasoning. Students were actively involved in searching for information on the WQS by using multiple representations to answer questions. They engaged in scientific reasoning, argumentation, and collaborative problem solving in order to understand the underlying causes and relationships between water quality indicators and land use. Results indicate that prolonged use with RiverWeb leads students to engage in collaborative reasoning and argumentation by automating low-level skills (e.g., finding different RiverWeb features by scanning the interface).

been able to answer.

Students from the LGSG group generated very complex argument structures as they attempted to understand the information. In the following example, June is working at the computer and a student expresses difficulty in understanding the relationship between nitrogen, phosphorus, and pH. June realizes that she does not fully understand the relationship either, and she and Holly together work to co-construct an understanding of this relationship. In fact, the WQS models pH as dependent on the proportion of stream water from precipitation (acidic pH) versus the proportion from ground water (neutral or alkaline pH). The students have not come to the realization that the relationship between pH and nutrients is really a reflection of the effect of the amount of precipitation on both.

Example 2:

| Turn | Transcript |
|---|---|
| 1 | June: The less phosphorus, the higher the pH goes, so it lessens the pH. Well, no, the- when- So when the phosphorus does go down, the pH starts going up . . so . . . So it must lower- it must make it lower, nitrogen makes it higher, so. So- . that doesn't make any sense, because wouldn't you think of the nitrogen and phosphorus going in the water, that, you know, kind of like the same rate in the runoff, wouldn't it [unintell] That's not what everybody's been telling us in the class |
| 2 | Holly: I don't see it. |
| 3 | June: [unintell] [laughs] It makes it- It must make it lower the, |
| 4 | Holly: It decreases . . . |
| 5 | June: That doesn't make any sense though. . . |
| 6 | Holly: I'm confused. . . . |
| 7 | June: Because nitrogen makes the pH higher, right? . . . Well I don't- That's why they . . . Well they said both nitrogen and phosphorus make it higher. And this is saying phosphorus makes it lower. So if nitrogen makes it higher and phosphorus makes it lower and they both go into the water at the same time . . . how? |
| 8 | Stacy [Teacher]: OK. Good. |
| 9 | June: Phosphorus makes it lower. |
| 10 | Holly: Well, that doesn't make any sense |
| 11 | Stacy: Well, it- we don't know if the phosphorus *makes* it lower, or . a- and if you- if you look at . . there is a– there is a decreasing trend here. |
| 12 | Holly: Yeah. That's what I said. |
| 13 | Stacy: An increase in phosphorus- when phosphorus is high, when you see an increase in phosphorus, you see an increase- uh, a decrease in pH. OK. |
| 14 | Holly: Ohhhh. |

When self-regulating students had difficulty understanding unexpected findings or seemingly contradictory information, they engaged in help-seeking behavior (Newman, 2002) from peers and teachers. The self-regulating students also used some of the scientific assumptions underlying the representations provided by RiverWeb. They were metacognitively aware of their performance and addressed deficiencies by reviewing what they knew, reviewing their arguments, reviewing their problem solving steps, revisiting graphs generated by RiverWeb, reflecting on the quality of their answers, and seeking scaffolding from each other and/or teachers. Unfortunately, very few students displayed this ability to regulate their learning of science with RiverWeb.

Teacher-Scaffolded Learning (Level 3).

Teachers played a crucial role during collaborative problem-solving for both TSG and LGSG students by providing instruction (e.g., definitions), cognitive scaffolding (e.g., hints), motivational statements (e.g., encouragement), procedural help (e.g., instructions on using the interface), and instructions about how to do the task (e.g., which indicators to look at in order to answer the question).

Instruction. Teachers sometimes provided instruction when they realized students were lacking knowledge. Instruction included direct instruction before student problem solving in both declarative knowledge ("Toxins are . . . poisons and pesticides, herbicides") and procedural knowledge ("Think about what happens in a lumbered area, or what you expect to happen in a lumbered area, and therefore I would find more or less of this in the water"), explaining student answers ("[Looking at student scatterplot] So whenever, uh, say, the precipitation . . . and the phosphorus at Station 0 is anywhere near .1, it sends it relatively high at Station 2"), and giving students the answer ("[a forest] anchors the soil and it absorbs and holds moisture in the ground. If you chop the trees down, then you're going to end up with lots of runoff"). In addition, teachers in the LGSG condition helped students with goal setting ("You're doing lumbering compared to pristine. And you're going to check nitrogen and phosphorus and all those things").

Cognitive Scaffolding. Teachers facilitated students' use of strategies and prior knowledge by using various scaffolding techniques. These included hinting ("Before you make your prediction . . . you can keep the indicator button [down]") and pumping students with questions ("Do you understand what the scatterplot is?"). It was apparent that teachers' scaffolding provided different types of feedback, which the students could then use to compare to internal standards (Butler & Winne, 1995).

Some teacher scaffolding was teacher-initiated, while some was the result of students' adaptive help-seeking. In Example 3, the teacher stepped in to scaffold students' understanding of the relationship between air temperature and amount of precipitation by asking them to think through specific examples.

Example 3:

| Turn | Transcript |
|---|---|
| 8 | Stacy: OK, I have a question, I have a question about your precipitation, your arrow for your air temperature- air temperature affects- affects precipitation. Are you talking about, let's say today it's going to be 50 degrees, is it going to rain? |
| 9 | Theo: Mmmmm. |
| 10 | Henry: Yeah. |
| 11 | Stacy: Do you predict on- in April, because it's 70 degrees, is it going to rain? |
| 12 | Theo: Most likely. Most likely. |
| 13 | Henry: If it's 70 degrees, it's probably. |
| 14 | Stacy: Which day will it rain? . I'm just trying to pick- OK, we're looking at maybe seasons, it might have a- a higher chance it's going to rain, April showers. . .Are you talking about . the air temperature affects the *type* of precipitation, you probably would not get snow in August, right? |
| 15 | Theo: No. |
| 16 | Stacy: OK, so you- you're talking about the air temperature is affecting maybe the types. Uh, and I- and here, I'm looki- my other- my other, uh, thing that I'm talking about is, can we predict due to the air temperature . due to it being 80 degrees, can we t- say OK, it's going to rain at- every time it's 80 |

| | |
|---|---|
| | degrees. OK, OK, I just wanted to. |
| 17 | Henry: [unintell] |
| 18 | Stacy: So we could write down, here, take this, . . with orange [marker] for- for, uh, for air temperature the connector affects- could affec-, uh, affect- affects *types* of precipitation. So you can put maybe right here you can put, uh, types of. . . OK, precipitation causes runoff. . Runoff increases the sediments, uh, sediments contain nitrogen, phosphorus, heavy metals, and toxins. And, uh. |
| 19 | Connecting [unintell] affect the, uh, pH. |

The teacher used several instructional and scaffolding strategies to try to improve the students' answer, including examples and counterexamples (e.g., in turn 14, "April showers" and "you probably would not get snow in August"), restating student information (e.g., in turn 8, "your arrow for your air temperature affects . . . precipitation"), and asking pumping questions (e.g., in turn 14, "Which day will it rain?").

Motivation. Teachers provided motivational scaffolding by giving positive feedback ("You guys did a real good job") and offering choices ("I am going to let you guys choose between lumbering and agriculture").

Procedural Help. Teachers helped students use RiverWeb to answer their questions by explaining, e.g., how to exit the RiverWeb tour, which then enabled students to see more of the screen in the interface. Teachers also reminded students about different features of the interface, e.g., "Make sure you guys are answering the notebook questions."

Task Instructions. Teachers asked students to approach tasks in specified ways, e.g., "I want you to take maybe about 3 minutes to look at [your concept maps] together." Teachers also reminded students to type their answers into RiverWeb (rather than simply writing them on paper).

Peer-Scaffolded Learning.

In addition to teacher scaffolding, peers also provided key support for student learning. Peers provided both explanations (see example 4 below) and scaffolding.

Example 4:

| Turn | Transcript |
|---|---|
| 1 | Micki: OK. [laughs] I bet there's a lot of runoff, here. . . Oh, wow, look how much less runoff there is when you do strip cropping. . . . Huh? Yep, it's a whole lot more than that.: |
| 2 | Mark: It's 1.4 million times [unintell] |
| 3 | Micki: About a thousand. . . . |
| 4 | Mark: It's going towards. . . . one billion gallons. . . . . |
| 5 | Steve: Part of the reason is the agricultural area the actual land area, the sample, is bigger. |

In summary, both TSG and LGSG students' engaged in individual, co-constructed, and teacher scaffolded learning. However, the quality of individual and co-constructed learning between TSG and LGSG is consistent with the quantitative differences in student learning.

## Conclusion

This study examined the role of different goal-setting instructional interventions in facilitating high school students' regulation of their conceptual understanding of ecological systems while using a Web-based water quality simulation environment. Building on Winne and colleagues' information processing theory of SRL, we examined 1) students' self-regulation, 2) co-regulation, and 3) the role of the teacher as an external regulator during a knowledge construction activity. Sixteen 11$^{th}$ and 12$^{th}$ grade high school students were randomly assigned to one of two goal-setting instructional conditions (teacher-set goals [TSG] and learner-generated sub-goals [LGSG]) and used RiverWeb$^{SM}$ collaboratively, during a three-week curriculum on environmental science. The students' emerging understanding was assessed using their pretest and posttest scores, and was also assessed through an analysis of their discourse during several collaborative problem-solving episodes. The LGSG condition facilitated a shift in students' mental models significantly more than did the TSG condition. Students in the LGSG condition were also much better at regulating and co-regulating their learning during the knowledge construction activity than were TSG students. In general, they planned and monitored their learning more efficiently by creating sub-goals, activating prior knowledge, and engaging in adaptive help-seeking. They also used more effective learning strategies and were more effective in handling task difficulties and demands than was the TSG group. Our results provide a valuable initial characterization of the complexity of self- and co-regulated learning in a complex, dynamic technology-enhanced student-centered classroom. We discuss our findings in terms of expanding existing conceptualizations of SRL, co-regulation, and the role of teachers and peers as external regulating agents. We will discuss how the results will be used to inform the design of new system features to support SRL and co-regulated learning.

**Acknowledgements**

The research described here was supported in part by funding awarded to the first author by the University of Maryland's Department of Human Development and College of Education. The authors would like to thank Mary Ellen Verona and the initial developers from Maryland Virtual High School (MVHS), David Curtis and the National Center for Supercomputing Applications (NCSA), several University of Maryland undergraduate students, Maryland-based secondary science teachers (Marilyn Leung, and Benita Rodriguez) and high school students for participating in our classroom studies.

**References**

Alexander, P. (1995). Superimposing a situation-specific and domain-specific perspective on an account of self-regulated learning. *Educational Psychologist, 30*(4), 189-193.

Azevedo, R. (2002). Beyond intelligent tutoring systems: Computers as MetaCognitive tools to enhance learning? *Instructional Science, 30*(1), 31-45.

Azevedo, R., Guthrie, J.T., Wang, H., & Mulhern, J. (2001). *Do different instructional interventions facilitate students' ability to shift to more sophisticated mental models of complex systems*? Paper presented at the Annual Conference of the American Educational Research Association, Seattle, WA.

Azevedo, R., Guthrie, J.T., Wang, H., & Mulhern, J. (2001, April). *Do different instructional interventions facilitate students' ability to shift to more sophisticated mental models of complex systems?* Paper presented at the Annual Conference of the American Educational Research Association, Seattle, WA.

Azevedo, R., Seibert, D., Guthrie, J.T., Cromley, J.G., Wang, H., & Tron, M. (2002, April). *How do students regulate their learning of complex systems with hypermedia?* Paper presented at the Annual Conference of the American Educational Research Association, New Orleans, LA.

Azevedo, R., Verona, M.E., & Cromley, J.G. (2001). Fostering students' collaborative problem solving with RiverWeb. In J.D. Moore, C.L. Redfield, & W.L. Johnson (Eds.), *Artificial intelligence in education: AI-ED in the wired and wireless future* (pp. 166-175). Amsterdam: IOS press.

Blumenfled, P., Marx, R., Patrick, H., & Krajcik, J. (1997). Teaching for understanding. In B. Biddle, T. Good, & I. Goodson (Eds.), *International handbook of teachers and teaching* (pp. 819-878). Netherlands: Kluwer.

Boekaerts, M., Pintrich, P., & Zeidner, M. (20000), *Handbook of self-regulation*. San Diego, CA: Academic Press.

Bronson, M.B. (2000). *Self-regulation in early childhood: Nature and nurture*. NY: Guildford.

Butler, D. & Winne, P.H. (1995). Feedback as self-regulated learning: A theoretical synthesis. *Review of Educational Review, 65*, 245-281.

Chi, M. T.H. (2000). Self-explaining: The dual processes of generating inference and repairing mental models. In R. Glaser, R. (Ed.), *Advances in instructional psychology: Educational design and cognitive science* (vol.5) (pp. 161-238). Mawah, NJ: Erlbaum.

Chi, M. T.H., de Leeuw, N., Chiu, M.-H., & LaVancher, C. (1994). Eliciting self-explanations improves understanding. *Cognitive Science, 18*, 439-477.

Chi, M. T.H., Siler, S., Jeong, H., Yamauchi, T., & Hausmann, R. (2001). Learning from human tutoring. *Cognitive Science, 25*, 471-534.

Gentner, D., & Stevens, A. (1983). *Mental models*. Hillsdale, NJ: Erlbaum.

Hannafin, M.J., & Land, S.M. (1997). The foundations and assumptions of technology-enhanced student-centered learning environments. *Instructional Science, 25*, 167-202.

Hegarty, M., & Just, M. (1993). Constructing mental models of machines from text and diagrams. *Journal of Memory & Language, 32*(6), 717-742.

Hogan, K. (1999). Thinking aloud together: a test of an intervention to foster students' collaborative scientific reasoning. *Journal of Research in Science Teaching, 36*(10), 1085-1109.

Jackson, S., Krajcik, J., & Soloway, E. (2000). MODEL-IT: A design retrospective. In M. Jacobson & R. Kozma (Eds.), *Innovations in science and mathematics education* (pp. 77-116). Mahwah, NJ: Elrbaum.

Land, S. (2000). Cognitive requirements for learning with open-ended learning environments. *Educational Technology Research & Development, 48*(3), 61-78.

Markman, A., & Gentner, D. (2001). Thinking. *Annual Review of Psychology, 52*, 223-247.

McCaslin, M., & Hickey, D. (2001). Self-regulated learning and academic achievement: A Vygtoskian perspective. In & B. Zimmerman & D. Schunk (Eds.), *Self-regulated learning and academic achievement: Theoretical perspectives* (pp. 227-252). Mawah, NJ: Erlbaum.

Narayanan, N.H., & Hegarty, M. (1998). On designing comprehensible interactive hypermedia manuals. *International Journal of Human-Computer Studies, 48*, 267-301.

Newman, R. (1994). Adaptive help seeking: A strategy of self-regulated learning. In Schunk & B. Zimmerman (Eds.), *Self-regulation of learning and performance: Issues and educational applications* (pp. 283-301). Hillsdale, NJ: Erlbaum.

Newman, R. (2002). "What do I need to do to suceed....when I don't understand what I'm doing!?" Developmental influences on students' adaptive help seeking. To appear in A. Wigfield & J. Eccles (Eds.), *The development of achievement motivation* (pp. 285-303). San Diego, CA: Academic Press.

Paris, S.G., & Paris, A.H. (2001). Classroom applications of research on self-regulated learning. *Educational Psychologist, 36*(2), 89-101.

Paris, S.G., Byrnes, J., & Paris, A.H. (2001). Constructing theories, identities, and actions of self-regulated learners. In & B. Zimmerman & D. Schunk (Eds.), *Self-regulated learning and academic achievement: Theoretical perspectives* (pp. 253-288). Mawah, NJ: Erlbaum.

Pintrich, P. (2000). The role of goal orientation in self-regulated learning. In M. Boekaerts, P. Pintrich, & M. Zeidner (Eds.) *Handbook of self-regulation* (pp. 452-494). San Diego, CA: Academic Press.

Pintrich, P.R., Zusho, A. (2002). The development of academic self-regulation: The role of cognitive and motivational factors. To appear in A. Wigfield & J. Eccles (Eds.), *The development of achievement motivation* (pp. 250-279). San Diego, CA: Academic Press.

Pressley, M., Ross, K., Levin, J., & Ghatala, E. (1984). Therole of strategy utility knowledge in chidlren'strategy decision making. *Journal of Experimental Child psychology, 38*, 491-504.

Randi, J., & Corno, L. (2000). Teacher innovations in self-regulated learning. In M. Boekaerts, P. Pintrich, & M. Zeidner (Eds.) *Handbook of self-regulation* (pp. 651-683). San Diego, CA: Academic Press.

Rogoff, B. (1999). Cognition as a collaborative process. In W. Damon, D. Kuhn, & R. Siegler (Eds.) *Handbook of child psychology* (vol. 2) (pp. 679-744). NY: Wiley.

Schunk, D. (2001). Social cognitive theory and self-regulated learning. In & B. Zimmerman & D. Schunk (Eds.), *Self-regulated learning and academic achievement: Theoretical perspectives* (pp. 125-152). Mawah, NJ: Erlbaum.

Schunk, D., & Zimmerman, B. (1997). Social origins of self-regulatory competence. *Educational Psychologist, 32*, 195-208.

Singer, J., Marx, R., Krajick, J., & Chambers, J. (2000). Constructing extended inquiry projects: Curriculum materials for science education reform. *Educational Psychologist, 35*(3), 165-178.

Vosniadou, S., & Brewer, W. (1992). Mental models of the earth: A study of conceptual change in childhood. *Cognitive Psychology, 24*(4), 535-586.

Vye, N., Schwartz, D., Bransford, J., Barron, B., Zech, L., & CTGV. (1998). SMART environments that support monitoring, reflection, and revision. In D. Hacker, J. Dunlosky, & A. Graesser (Eds.) *Metacognition in educational theory and practice* (pp. 305-346). Mahwah, NJ: Erlbaum.

Wallace, R., Kupperman, J., Krajcik, J., & Soloway, E. (2000). Science on the web: Students online in a sixth-grade classroom. *Journal of the Learning Sciences, 9*(1), 75-104.

White, B.Y., Shimoda, T.A., & Frederiksen, J.R. (2000). Facilitating students' inquiry learning and metacognitive development through modifiable software advisers. In S.P. Lajoie (Ed.), *Computers as cognitive tools II: No more walls: Theory change, paradigm shifts and their influence on the use of computers for instructional purposes* (pp. 97-132). Mawah, NJ: Erlbaum.

Winne, P. H. (1995). Inherent details in self-regulated learning. *Educational Psychologist, 30*, 173-187.

Winne, P. H. (1996). A metacognitive view of individual differences in self-regulated learning. *Learning and Individual Differences, 8*, 327-353.

Winne, P. H. (2001). Self-regulated learning viewed from models of information processing. In B. J. Zimmerman and D. H. Schunk (Eds.), *Self-regulated learning and academic achievement: Theory, research, and practice* (pp. 153-189). New York: Longman.

Winne, P.H., & Hadwin, A. (1998). Studying as self-regulated learning. In D. Hacker, J. Dunlosky, & A. Graesser (Eds.), *Metacognition in educational theory and practice* (pp. 279-306) Hillsdale, NJ: Elrbaum.

Zimmerman, B. (1986). Development of self-regulated learning: Which are the key sub-processes? *Contemporary Educational Psychology, 16*, 307-313.

Zimmerman, B. (2002). Achieving academic excellence: A self-regulatory perspective. In M. Ferrari (Ed). . *The pursuit of excellence through education. The educational psychology series*. (pp. 85-110). Mahwah, NJ, US: Erlbaum.

Zimmerman, B. (2000). Attaining self-regulation: A social cognitive perspective. In M. Boekaerts, P. Pintrich, & M. Zeidner (Eds.), *Handbook of self-regulation* (pp. 13-39). San Diego, CA: Academic Press.

Zimmerman, B. (2001). Theories of self-regulated learning and academic achievement: An overview and analysis. In & B. Zimmerman & D. Schunk (Eds.), *Self-regulated learning and academic achievement: Theoretical perspectives* (pp. 1-37). Mawah, NJ: Erlbaum.

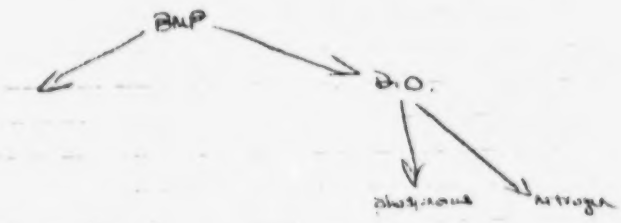
Zimmerman, B., & Schunk, D. (2001). *Self-regulated learning and academic achievement: Theoretical perspectives*. Mawah, NJ: Erlbaum.

Zimmerman, B., & Risemberg, R. (1997). Self-regulatory dimensions of academic learning and motivation. In G. Phye (Ed.), *Handbook of academic learning: Construction of knowledge*. San Diego, CA: Academic Press.

Table 1

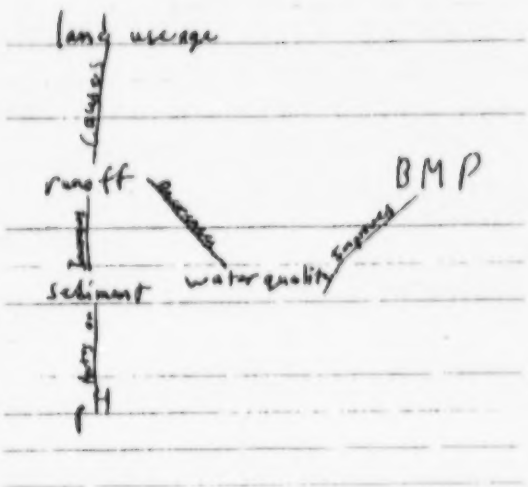
Necessary Features for Each Type of Mental Models of Water Quality in a Watershed

1 - No understanding demonstrated. Either no concept map is drawn or the connections drawn between factors are all or almost all incorrect.




2 - Minimal understanding demonstrated. Some discrete linkages are made, but there is no coherence. Some single level connections are made (e.g., precipitation to runoff and nitrogen, toxins, and land usage to water quality), but there are more connections that make no sense.

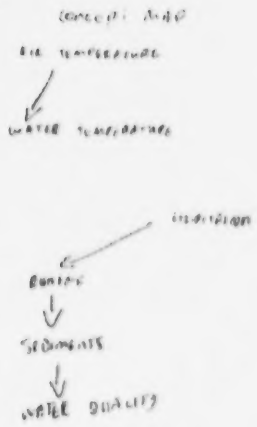
3 - Some understanding of multiple levels of causality is demonstrated. Bi-level causal relationships are indicated. Precipitation or land usage causes runoff and runoff contains one or more chemical/physical pollutants.



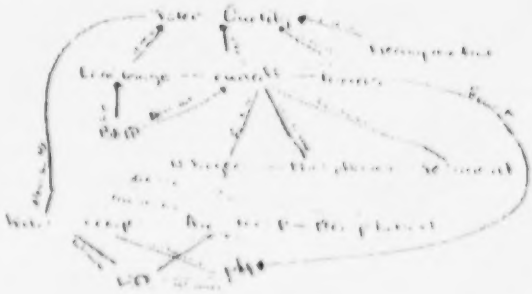



BEST COPY AVAILABLE

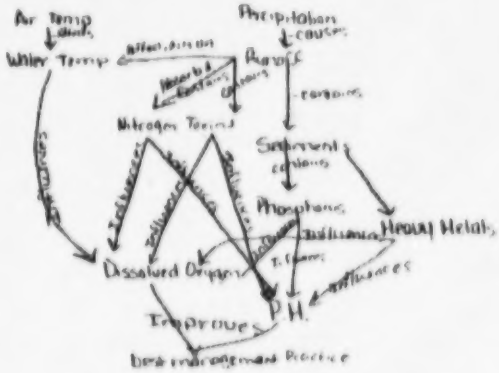
4 - A better understanding of multiple levels of causality is demonstrated. Tri-level causal relationships are indicated or the bi-level relationships in score 3 are supplemented by a new strand to the concept map. The former would be illustrated by a map showing: Precipitation or land usage causes runoff, runoff contains one or more chemical/physical pollutants, and one or more pollutants affect pH or water quality. The latter would be illustrated by a map showing: Precipitation or land usage causes runoff, runoff contains one or more chemical/physical pollutants, and air temperature affects water temperature or water temperature affects dissolved oxygen.



5 - Breadth and depth are included in the concept map. Tri-level causal relationships are indicated and a new strand is added to the concept map. For example: Precipitation or land usage causes runoff, runoff contains one or more chemical/physical pollutants, and one or more pollutants affect pH or water quality shows a tri-level map. The addition of air temperature affects water temperature or water temperature affects dissolved oxygen shows breadth in the concept map.



6 - Breadth, depth, and the differences in the water solubility of nitrogen and phosphorus are demonstrated. The concept map has all of the qualities needed for a score 5 plus it shows that nitrogen comes from runoff while phosphorus appears in sediments.




7 - A third level of breadth is added. The concept map has all of the qualities needed for a score 6 plus it shows that BMP affects land usage.

BEST COPY AVAILABLE

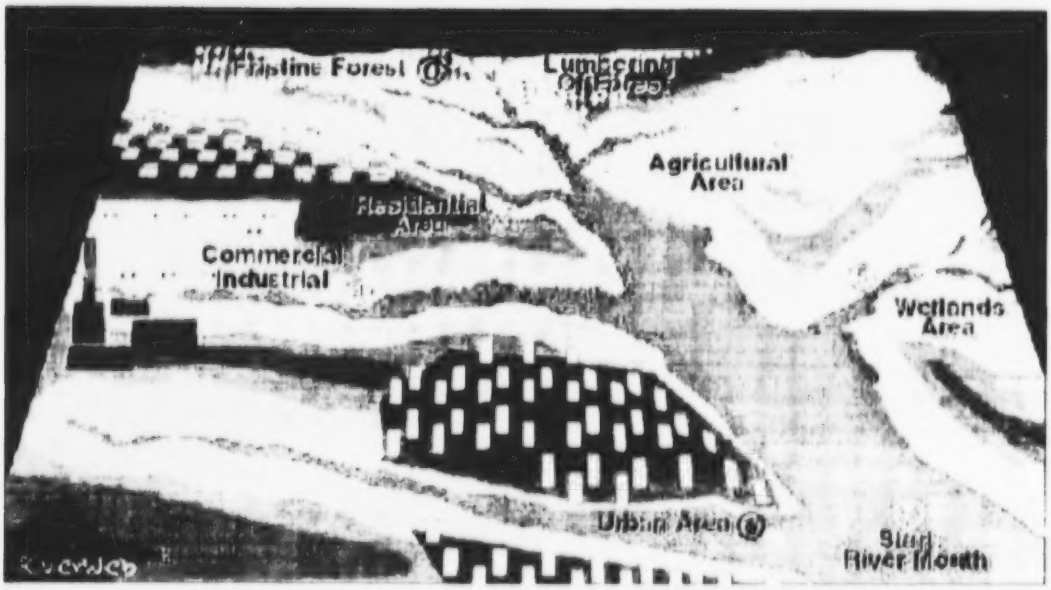



Figure 1. RiverWeb interface displaying the seven watershed subregions

BEST COPY AVAILABLE

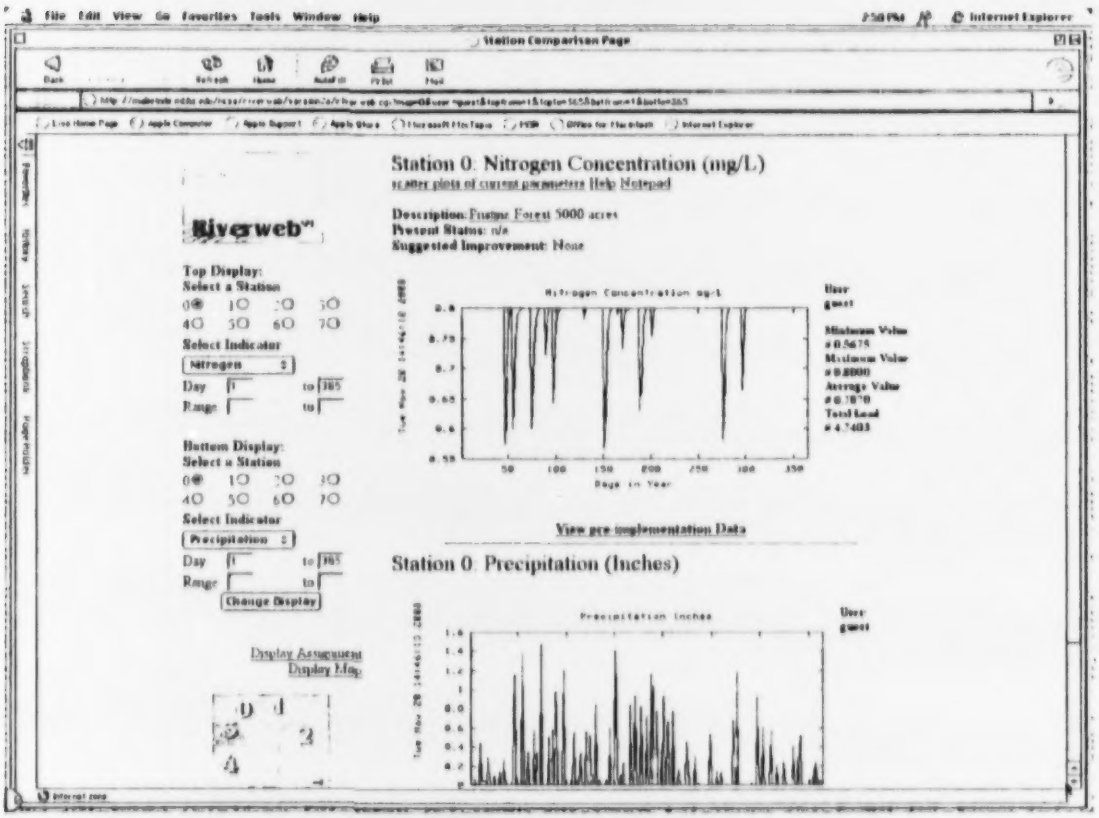



Figure 2. RiverWeb interface illustrating a student comparing the variation in nitrogen (top window) and precipitation (bottom window) over time in the pristine forest (Station 0).

BEST COPY AVAILABLE

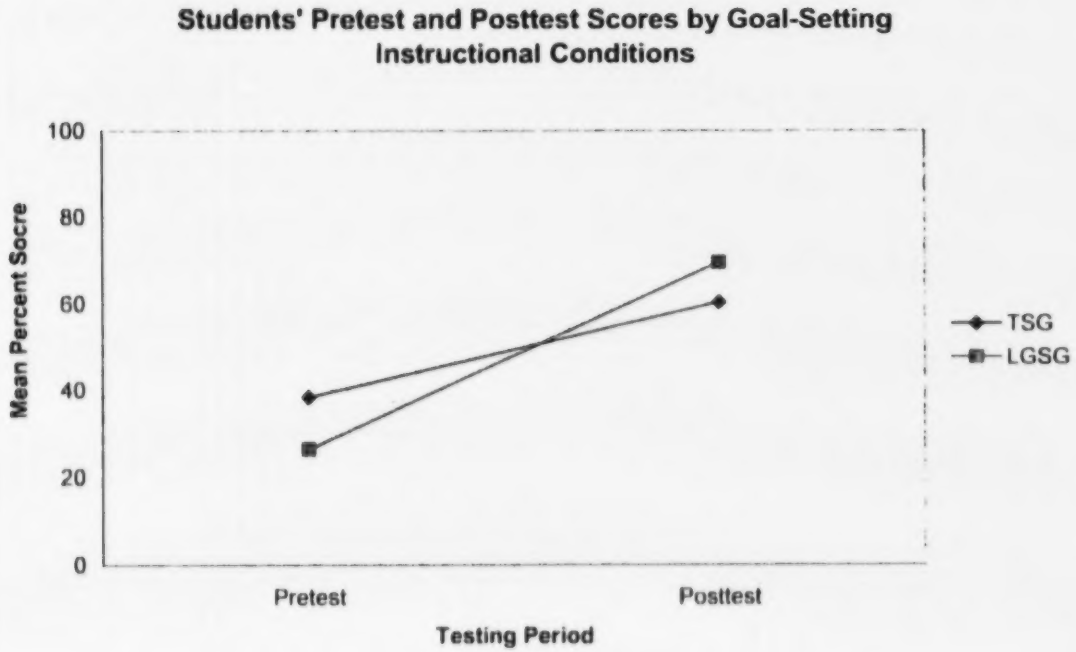



Figure 3. Students' Pretest and Posttest Scores by Goal-Setting Instructional Condition.

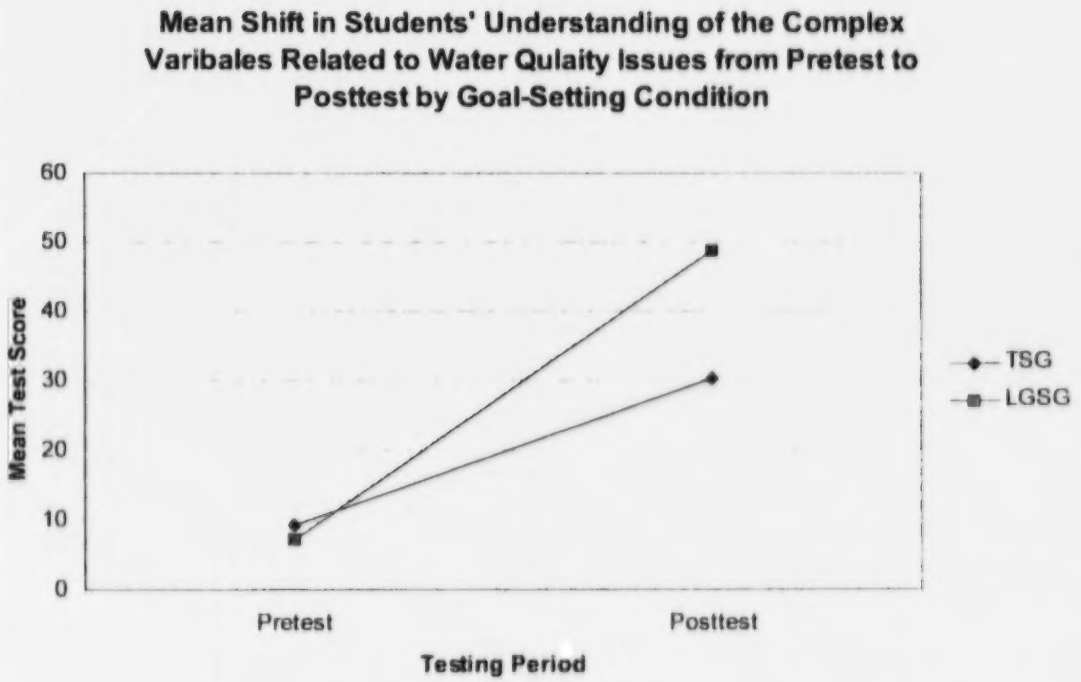



Figure 4. Mean Shift in Students' Understanding of the Complex Variables Related to Water Quality Issues from Pretest to Posttest by Goal-Setting Instructional Condition.

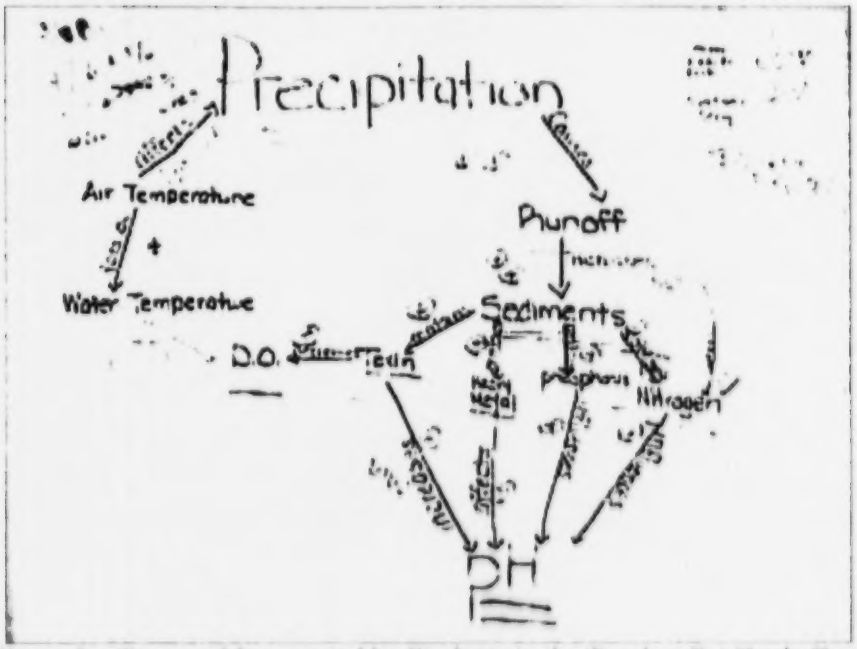



Figure 5a. Concept Map created by Students in the Teacher-Set Goals Group.

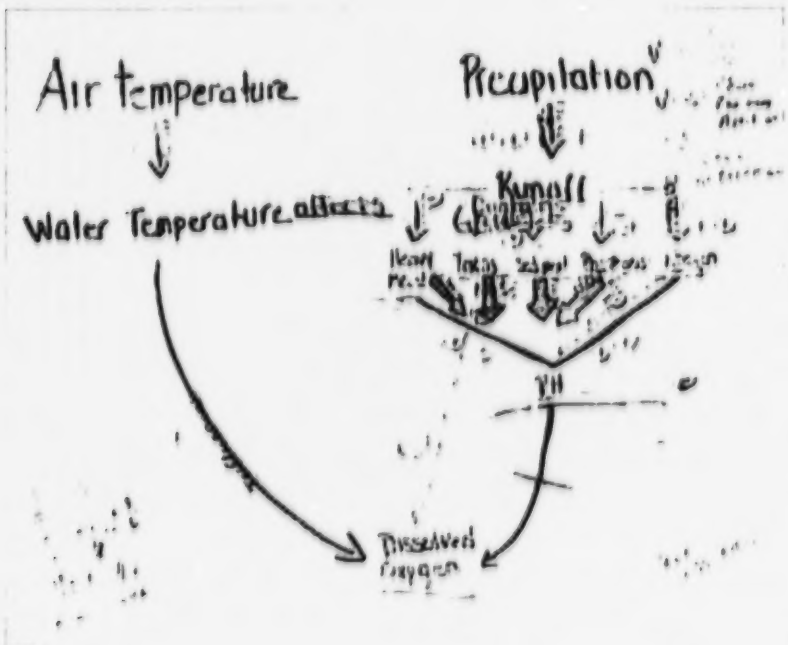



Figure 5b. Concept Map created by Students in the Learner-Generated Sub-Goals Group



BEST COPY AVAILABLE

**U.S. Department of Education**
*Office of Educational Research and Improvement (OERI)*
*National Library of Education (NLE)*
*Educational Resources Information Center (ERIC)*

# REPRODUCTION RELEASE

(Specific Document)

TM035004

## I. DOCUMENT IDENTIFICATION:

Title: Do different goal-setting conditions facilitate student's ability to regulate their learning of complex science topics with RiverWeb?

Author(s): Roger AZEVEDO, Susan RAGAN, JENNIFER G. CROMLEY, + STACY PRITCHETT

Corporate Source: —

Publication Date: April 2002

## II. REPRODUCTION RELEASE:

In order to disseminate as widely as possible timely and significant materials of interest to the educational community, documents announced in the monthly abstract journal of the ERIC system, *Resources in Education* (RIE), are usually made available to users in microfiche, reproduced paper copy, and electronic media, and sold through the ERIC Document Reproduction Service (EDRS). Credit is given to the source of each document, and, if reproduction release is granted, one of the following notices is affixed to the document.

If permission is granted to reproduce and disseminate the identified document, please CHECK ONE of the following three options and sign at the bottom of the page.

The sample sticker shown below will be affixed to all Level 1 documents

PERMISSION TO REPRODUCE AND DISSEMINATE THIS MATERIAL HAS BEEN GRANTED BY

Sample

TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)

1

Level 1 ☑

Check here for Level 1 release, permitting reproduction and dissemination in microfiche or other ERIC archival media (e.g., electronic) and paper copy

The sample sticker shown below will be affixed to all Level 2A documents

PERMISSION TO REPRODUCE AND DISSEMINATE THIS MATERIAL IN MICROFICHE, AND IN ELECTRONIC MEDIA FOR ERIC COLLECTION SUBSCRIBERS ONLY, HAS BEEN GRANTED BY

Sample

TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)

2A

Level 2A ☐

Check here for Level 2A release, permitting reproduction and dissemination in microfiche and in electronic media for ERIC archival collection subscribers only

The sample sticker shown below will be affixed to all Level 2B documents

PERMISSION TO REPRODUCE AND DISSEMINATE THIS MATERIAL IN MICROFICHE ONLY HAS BEEN GRANTED BY

Sample

TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)

2B

Level 2B ☐

Check here for Level 2B release, permitting reproduction and dissemination in microfiche only

Documents will be processed as indicated provided reproduction quality permits.
If permission to reproduce is granted, but no box is checked, documents will be processed at Level 1.

*I hereby grant to the Educational Resources Information Center (ERIC) nonexclusive permission to reproduce and disseminate this document as indicated above. Reproduction from the ERIC microfiche or electronic media by persons other than ERIC employees and its system contractors requires permission from the copyright holder. Exception is made for non-profit reproduction by libraries and other service agencies to satisfy information needs of educators in response to discrete inquiries.*

**Sign here, → please**

| | |
|---|---|
| Signature: Roger Azevedo | Printed Name/Position/Title: ROGER AZEVEDO, ASSISTANT PROF. |
| Organization/Address: UMD | Telephone: 301-405-2799 FAX: 301-405-2891 |
| | E-Mail Address: RA169@umail.umd.edu Date: 5/28/03 |

(Over)

## III. DOCUMENT AVAILABILITY INFORMATION (FROM NON-ERIC SOURCE):

If permission to reproduce is not granted to ERIC, *or*, if you wish ERIC to cite the availability of the document from another source, please provide the following information regarding the availability of the document. (ERIC will not announce a document unless it is publicly available, and a dependable source can be specified. Contributors should also be aware that ERIC selection criteria are significantly more stringent for documents that cannot be made available through EDRS.)

| |
|---|
| Publisher/Distributor: |
| Address: |
| Price: |

## IV. REFERRAL OF ERIC TO COPYRIGHT/REPRODUCTION RIGHTS HOLDER:

If the right to grant this reproduction release is held by someone other than the addressee, please provide the appropriate name and address:

| |
|---|
| Name: |
| Address: |

## V. WHERE TO SEND THIS FORM:

Send this form to the following ERIC Clearinghouse:

**ERIC CLEARINGHOUSE ON ASSESSMENT AND EVALUATION**
**UNIVERSITY OF MARYLAND**
**1129 SHRIVER LAB**
**COLLEGE PARK, MD 20742-5701**
**ATTN: ACQUISITIONS**

However, if solicited by the ERIC Facility, or if making an unsolicited contribution to ERIC, return this form (and the document being contributed) to:

**ERIC Processing and Reference Facility**
**4483-A Forbes Boulevard**
**Lanham, Maryland 20706**

**Telephone: 301-552-4200**
**Toll Free: 800-799-3742**
**FAX: 301-552-4700**
**e-mail: ericfac@inet.ed.gov**
**WWW: http://ericfacility.org**

EFF-088 (Rev. 2/2001)